PacRIM II: A Review of AirSAR Operations and System Performance

Delwyn Moller, Anhua Chu, Yunling Lou, Timothy Miller, Ellen O'Leary
Jet Propulsion Laboratory, California Institute of Technology
4800 Oak Grove Drive, Pasadena, CA 91109
T: 626.354.9780 / F: 626.393.3077 / delwyn.moller@jpl.nasa.gov

Abstract—NASA's AirSAR instrument has long been a heavily utilized resource in the international remote sensing community, including, most recently, the very successful PACRIM II mission. In this paper we briefly review the AirSAR system, its expected performance, and quality of data obtained during that mission. We discuss the system hardware calibration methodologies, and present quantitative performance values of radar backscatter and interferometric height errors (random and systematic) from PACRIM II calibration data. We also summarize the various anomalies experienced during the PACRIM II mission, their potential impacts on data quality, and possible solutions to those problems.

Finally, in light of these assessments, we discuss near-term system enhancements, and expected performance improvements for future AirSAR missions. In particular, we present a redesigned data acquisition system that promises to improve data reliability and system flexibility while increasing data-throughput. One distinct advantage of this system is it will allow us to collect wide-swath high-bandwidth data thereby making data collection more efficient when high bandwidth area imagery is required.

I Introduction

JPL's airborne synthetic aperture radar (AirSAR) [1], [2] is a unique system, comprising three radars at C-, L- and P-bands. AirSAR data collections are flexible; fully polarimetric data (POLSAR) can be collected at all three frequencies, while cross-track interferometric data (TOPSAR) and along-track interferometric (ATI) data can be collected at C- and L-bands [3]. This configurability has made AirSAR a heavily utilized resource within the USA and internationally. The 2000 PACRIM II mission was AirSAR's most ambitious deployment to date. In addition to collecting AirSAR data, hyperspectral data were also collected over most of the same sites by the Master instrument, an airborne Modis/Aster simulator.

Over a period of 3 months the AirSAR and Master instruments aboard the NASA/Dryden DC-8 aircraft collected data over 18 countries and territories around the pacific rim. The plane was staged at 15 bases in 9 countries. Data were collected on 46 flight days over 318 flight hours. A total of 648 flight lines covering 54623km (along the flight path) were collected with a 94% success rate of planned vs executed lines. Some lines were cancelled due to weather or hardware considerations.

The PACRIM II mission was a collaboration between NASA and the participating countries. While data was collected for NASA-funded US investigators, the majority of data were collected for researchers within each country. NASA/JPL worked with a central organization (university or research institute) to coordinate data collection in each country. In turn, these points-of-contact solicited requests for data from investigators within their country. A wide range of research objectives and applications will be addressed with the data that were collected. For AirSAR these applications include

- biomass estimation/carbon sequestration studies
- soil moisture measurements
- vegetation classification
- land-use classification
- urban mapping/growth studies
- radar techniques and calibration
- archeological exploration
- along-track interferometry to measure ocean current direction and velocity
- wetland, flooded forest classification
- natural hazard monitoring and studies
- geologic mapping

The individual applications determined the operational mode for each flight line. Table I summarizes the statistics of data collection modes for PACRIM II.

This paper reviews PACRIM II from the AirSAR system and operations perspective. Section II discusses in-flight system operations focusing on new utilities which were enhancements for PACRIM II. Section III focuses first on calibration methodology then moves on to itemize system performance issues we encountered. Finally Section IV forecasts improvements to AirSAR for a possible PACRIM III mission in 2003.

II System Operations

For PACRIM II, AirSAR incorporated a number of enhancements to improve operations and in-flight system health monitoring. Perhaps most notable was the addition of a computer that generated near real-time interferograms and single channel SAR images (for the polarimetric modes). This allowed us to process small sections of selected datatakes through to images/interferograms, often on the same flight day. This ability provides a strong measure of confidence that the radars are operating satisfactorily and, in the case of interferograms, that our motion compensation data is not corrupted. This

The research described in this paper was carried out by the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration

some operational issues which deserve mention.

One of the primary system problems encountered on PACRIM II was phase jitter in the digital chirp generators (DCG). The DCG's would only operate stably within a fairly narrow temperature range and it was often necessary to cool or warm the rack. This especially affected the P-band radar. A combination of closely monitoring the temperature and frequently checking the phase stability enabled us to minimize the impact of this problem. As a result we have not seen significant evidence of data corruption in the processing. The DCG problems have been traced to a design flaw and are currently being redesigned.

Another significant problem encountered in-flight was the stability of the EGI which provides critical motion compensation and position data. This was an issue throughout the mission which cost flight hours and some data lines. The most notable impact was that no AirSAR data was collected on the Townsville to Alice Springs, Australia transit after in-flight and ground resets of EGI failed. Following this a flight day was postponed and the DC8 remained in Alice Springs while the EGI was fixed under the guidance of the manufacturer in Florida. Despite this, EGI stability continued to be a major issue with in-flight and ground resets being necessary on a number of occasions. Since returning, the EGI has been updated with a new software version. We plan to fly with an EGI engineer on board for the engineering checkout flights of our next deployment.

IV Future Improvements

As previously mentioned, a critical improvement to AirSAR will be the new DCG's. Having identified a design flaw in the current DCG's, they have been redesigned and will be integrated into AirSAR by the end of 2001 and tested in our next deployment (early 2002).

A further upgrade/modification that will be integrated into AirSAR for the 2002 deployment is a smaller, more efficient P-band transmitter which will more than double the transmitted power from 850W to 2kW. The increase in power will mitigate our sensitivity to radio frequency interference which is very prevalent at P-Band. The new transmitter will first be flown 2002.

Before PACRIM III we propose to upgrade AirSAR's data acquisition system with a new state-of-the-art data acquisition system primarily using commercial off-the-shelf (COTS) componentry. The proposed design yields a number of improvements over the current AirSAR digital sytem. These include:

- increased reliability.
  - Data-glitchs are observed in current system which serve to wipe-out entire range-lines.
  - The existing system also has several components which are"single-point-failures".
- the full beam-limited swath-width can be acquired, even at 80MHz bandwidth. Currently there is a data-flow bottleneck of 5MB/s per channel (30MB/s aggregate throughput) and higher bandwidth data can only be collected by reducing the swath-width. The new data acquisition system's aggregate throughput will exceed 120MB/s
- improved in-flight health monitoring and near-real-time processing. In-flight visibility of the data is critical for detecting system hardware problems expeditiously.
- compliance with industry standards and protocols. This will enhance AirSAR's readiness to act as a technology testbed. AirSAR's directive to demonstrate and develop new technology is dependent on a flexible, modular and standardized design.
- the modular design will make the addition of data channels (for single-pass Polarimetric interferometry or even another radar) relatively straight-forward and inexpensive.

We anticipate that, by PACRIM III, we will be using a new processor to process the data. This processor will improve the image quality, with better calibration and projection implementations. The result will be enhanced products in terms of both absolute and relative errors.

V Conclusions

This paper summarized AirSAR's participation in PacRIM II, detailing both system improvements and difficulties encountered. PACRIM II was an ambitious undertaking logisitically, technically and scientifically that overall can be deemed a success. A number of improvements are anticipated for PACRIM III in 2003. These enhancements promise to benefit AirSAR users in terms of data quality delivered.

References

[1] Zebker, H. A., Madsen, S. N., Martin, J., Wheeler, K. B., Miller, T., Lou, Y, Alberti, G., Vetrella, S., and Cucci, A. The TOPSAR interferometric radar topographic mapping instrument. *IEEE Transaction on Geoscience and Remote Sensing*, 30(5):933–940, 1992.

[2] Madsen, S. N., Martin, J. M., and Zebker, H. A. Analysis and evaluation of the NASA/JPL TOPSAR across-track interferometric SAR system. *IEEE Transaction on Geoscience and Remote Sensing*, 33(2):383–391, 1995.

[3] Lou, Y., Imel, D., Chu, A., Miller, T., Moller, D., and Skotnicki, W. Progress report on the nasa/jpl airborne synthetic aperture radar system. *2001 International Geoscience and Remote Sensing Symposium Proceedings*, 2001.

[4] Chu, A., Tung, W., and OLeary, E. The data processing and calibration for the pacific rim II mission. *2001 International Geoscience and Remote Sensing Symposium Proceedings*, 2001.

[5] Freeman, A. SAR calibration: An overview. *IEEE Transaction on Geoscience and Remote Sensing*, 30(6):1107–1121, 1992.

[6] van Zyl, J. J. Calibration of polarimetric radar images using only image parameters and trihedral corner reflector responses. *IEEE Transaction on Geoscience and Remote Sensing*, 28(3):337–348, 1990.